DEPARTMENT OF COMMERCE

TECHNOLOGIC PAPERS
OF THE
BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 81

LIQUID-MEASURING PUMPS

BY

F. J. SCHLINK, Associate Physicist
Bureau of Standards

[2d Edition]
ISSUED OCTOBER 20, 1917

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LIQUID-MEASURING PUMPS[1]

By F. J. Schlink

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INTRODUCTION

The present importance of the liquid-measuring pump is largely due to the great extent and amount of the sale of gasoline as a motor fuel. Although measuring pumps are used in other lines, notably in the grocery and wholesale drug trades, it is nevertheless a fact that by far the greatest number are used in the sale of gasoline to motorists; it appears that a very high proportion of gasoline sold in public places for this use is sold through measuring pumps.

[1] Read at the Eleventh Annual Conference on the Weights and Measures of the United States on May 23, 1916.

The rising price of gasoline and the small margin of profit to the retailer, often amounting to but 1 or 2 cents on the gallon, call for accurate measurement, and make the question of the design and testing of measuring pumps an important one.

The writer is informed that there are more than 7000 measuring pumps in use in Greater New York alone. Approximately 39 firms are engaged in the manufacture of measuring pumps and systems.

The wide adoption of measuring pumps has been due to a number of reasons, and the advantages here mentioned must be carefully considered in the drafting of specifications and regulations for their governance. First may be mentioned convenience, since the measuring pump provides, through the hose which is commonly attached, a means for delivering gasoline directly into the supply tank of an automobile expeditiously, without spilling and soiling the car or the premises, and with a minimum of waste and evaporation.

The second and most important factor is that of safety. The highly volatile and inflammable nature of gasoline makes its handling in open cans or measures undesirable; the fire risk involves not merely the premises of the merchant but also the automobile, property, and person of the purchaser as well. Gasoline fires are particularly dangerous, on account of the quickness with which they spread and the difficulty of their extinguishment. So important is the fire hazard in the dispensing of gasoline that several associations of insurance underwriters have framed special regulations concerning the handling and storage of gasoline in public garages and filling stations, while the need for protection of communities against these same hazards has caused the enactment of many city ordinances similarly restricting this business.

A measuring pump may be defined as a pump, or a combination of a pump with other mechanism, adapted for the measurement of fluids in definite quantities by volume.

In many instances the pump itself forms the volumetric measuring device, discharging a definite quantity for each stroke or cycle, and in other types of apparatus the pump is only auxiliary, operating to fill or empty a suitable measuring chamber in which the actual apportionment of the fluid takes place. In this paper endeavor will be made to outline the principal points of interest and value to the inspector of weights and measures relative to the design, construction, inspection, testing, and supervision of measuring pumps coming within his jurisdiction.

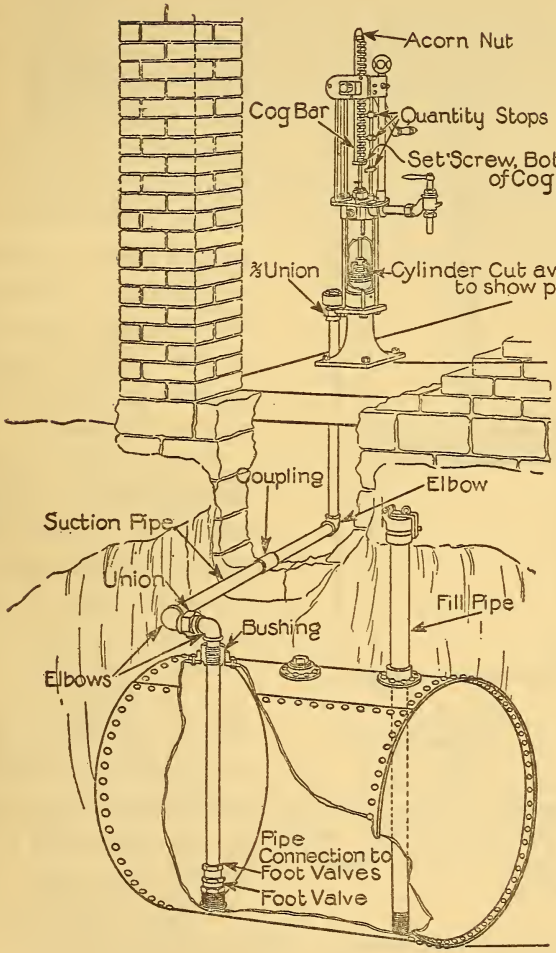

FIG. 4.—*Typical piston-type measuring pump installation, showing arrangement of tank, piping, valves, etc.*

PISTON-TYPE MEASURING PUMPS

The ordinary piston pump, familiar to all in numerous industrial applications, possesses the measuring property if means are provided for defining the length of stroke and applying auxiliary mechanism which will insure that each stroke of the piston will discharge a volume of liquid equal to the space volume generated by the piston in its travel. This requires that valves be tight and the piston close-fitting, so as to prevent the return of the liquid to the supply tank or cistern, as well as leakage or slippage of liquid past the piston during its stroke. Other requisites will appear in the later portions of this discussion.

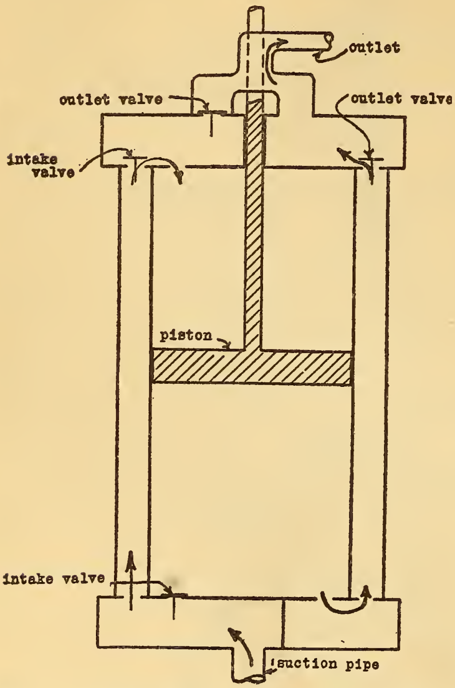

Fig. 5.—*Diagram of double-acting pump, showing arrangement of valves. This type discharges on both up and down strokes. When valves are in position shown, the piston is descending*

Piston pumps may be either single-acting or double-acting; that is, they may discharge liquid either on the upstroke only or they may discharge on both the up and down strokes. As a matter of fact, single-acting piston pumps do discharge on the return stroke, but the amount of this discharge is small and in amount equal to the volume of the piston rod. Occasionally two single-acting pumps are used in combination, discharging on alternate strokes. The differences between the single and double-acting pumps are of construction only; the principles on which they work are too well known to need elaboration here. The points to be considered in their test are the same for each and will be taken up in detail later.

In addition to the ordinary, or "reciprocating-piston" pumps, rotating-piston pumps are used. Those used for measuring purposes are nearly all of one type of construction, which is illustrated in Fig. 7. These pumps are used principally for measurement

FIG. 1.—*Example of large filling station, having 10 measuring pumps for gasoline and 4 for lubricating oil*

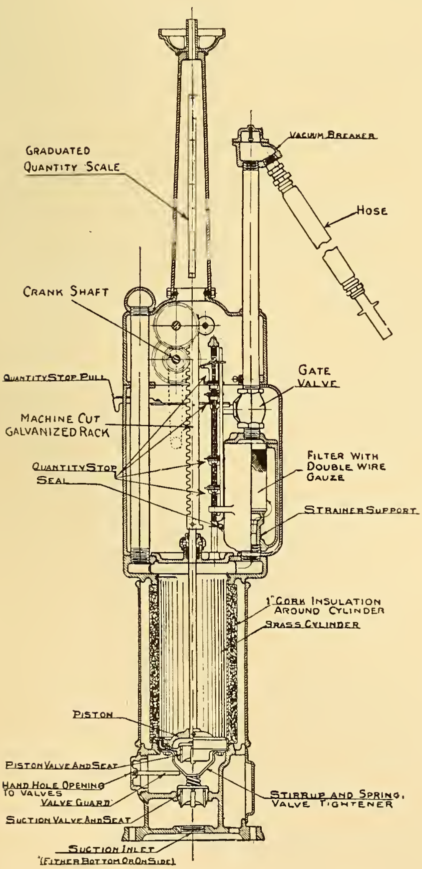

FIG. 2.—*Sectional elevation of typical piston-type measuring pump*

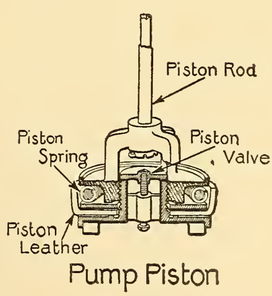

FIG. 3.—*Section of piston, showing cup-leather, expander-spring, and lift valve*

of molasses, tar, and similar viscous liquids; however, some are in use for the dispensing of kerosene, gasoline, and similar mobile liquids. Obviously, when such pumps are employed for measuring purposes, the fit of the operating parts must be very accurate, and especially is this true in the case of the less viscous liquids, since more opportunities for leakage are present in this type of pump on account of the presence of a greater number of submerged impelling parts. Another factor of importance is that in this type of pump it is not feasible to use a flexible packing or piston material, which has the property of yielding and conforming closely to the enveloping surface; on this account, since the relative motion occurs between metallic surfaces, great care is required in obtaining smooth surfaces and nicely fitting parts.

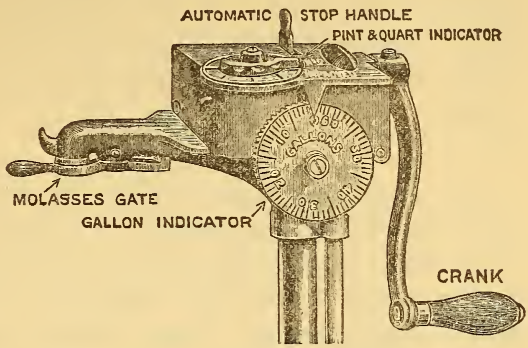

FIG. 6.—*Rotary measuring pump, commonly used for molasses, tar, and other viscous liquid*

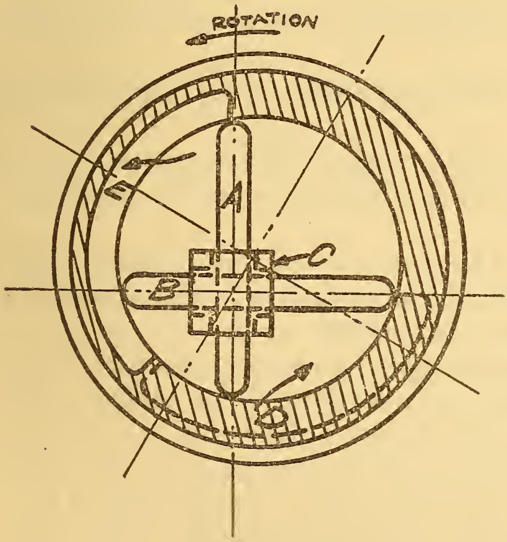

FIG. 7.—*Diagram showing operation of rotary measuring pump of Fig. 6. The bars A and B slide in the central shaft C. As the shaft rotates, the sliders take in the liquid at D and force it out through the port E*

This type of pump is often made so as to be driven by hand or other power, and one form is operated as a motor by the passage through it of the liquid being measured, under suitable pressure. In the latter case it becomes a true "liquid meter" and not a measuring pump. In one case the effect of slippage will tend to make the instrument register more than the true amount passing, and in the other case less than this amount.

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A modification of this type is made which comprises an auxiliary device arranged to shut off the flow of liquid after a certain predetermined quantity has passed, thus making it possible to discharge automatically into a container any desired quantity of liquid; after such discharge the flow will cease, the amount passing having in the same operation been registered upon a suitable counter.

COUNTERS

Most measuring pumps of the mechanical type are equipped with a counter or tally, sometimes incorrectly termed a "meter," the function of which is to count and indicate the number of full strokes, which have been completed. These counters are essential appurtenances, since without their use disputes may readily arise between the purchaser and the seller as to the number of units which have been discharged. Obviously, in cases of this kind both parties may believe their count to be the correct one, and a satisfactory adjustment may be reached only after much unpleasantness.

The following are the principal ends to be sought in the design of these tallying devices:

(*a*) Maximum visibility and readibility to both operator and purchaser.

(*b*) Tallying only very near to the end of the stroke. This is important in order to increase the difficulty of and the temptation to "short-stroking."

(*c*) Accurate pointing of the hand to the correct figure. Constructions which will permit the hand to stop at a position intermediate to two figures are to be avoided.

One of the most common types of counters used is, in the writer's opinion, unsuitable, its indications being visible on the edge or periphery of a relatively thick disk; such counters are usually so placed that their indications are readable only from the position of the operator of the pump. Counters should have a dial reading on a plane face, facing the purchaser; if the pump is accessible for filling motor tanks from either front or back, a dial should be provided at both of these aspects.

METERING SYSTEMS

The next type of pump to be taken up is one in which the pump acts merely to discharge the liquid through a meter. One type utilizes the lower specific gravity of gasoline to maintain its

separation from a quantity of water upon which it floats, the water acting as a sort of liquid piston, so that by forcing additional water into the containing tank, as from a city water supply system, the gasoline is displaced in like quantity and delivered through suitable piping to a convenient outlet. Fig. 8 shows the operation of the so-called hydraulic system.

The application of the so-called hydraulic system at once raises the question: Is there any appreciable intersolution of the two liquids; that is, does the water dissolve into the gasoline and the gasoline dissolve into the water? In the first case the result would be a *dilution* of the commodity, and in the second case a *loss* of the commodity into the sewer into which the water contents of the system are finally drained. Unfortunately, we have been unable to give this question the detailed study and experiment which it deserves, but the data available seem to indicate that the gasoline received from the refinery is a saturated solution of water; that is, it contains all the water which it will carry at the temperature of the last process, since, after being treated with sulphuric acid in the refining process the gasoline is thoroughly washed with water to remove as far as possible all traces of acid. During this process the gasoline undoubtedly becomes saturated with water (the term is used in the technical sense). Later, as the temperature changes, the gasoline will change its water content, so as to come, if conditions permit, into a solution equilibrium which tends to obtain at a particular temperature. It is this fact which accounts for the frequently noted presence of water in gasoline which at the time of purchase was patently free from water. In view of the facts just adduced, it is thought that solution of water into the gasoline is a factor which may be safely neglected. With regard to solution in the other direction, it may be said that for gasoline of very high grade, which is the only one upon which any data have been obtained, the water might take up 0.2 per cent by weight of gasoline at a temperature of 22° C. With the modern gasolines, which, with the exception of the casing head and blended products, are of much heavier frac-

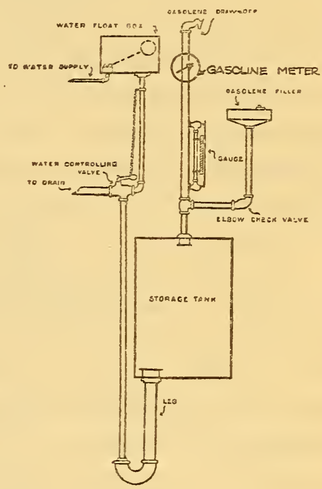

FIG. 8.—*Hydraulic system of storage and metering*

tions than the gasoline just mentioned, facts seem to indicate that the amount of solution of gasoline into the water is very small and probably entirely negligible, especially in view of the fact that conditions in the storage tank are not such as to favor rapid diffusion; to prevent this diffusion as far as possible, baffle plates or their equivalent should be provided to prevent agitation of the mass when either water or gasoline are added to the displacement tank.

In the pneumatic system the pressure of air or an inert gas is applied to the surface of the liquid in a tank, the liquid being forced into the piping system ready to discharge through a meter at the opening of a valve. Another type uses a piston pump of such design as to eliminate pulsations as perfectly as possible; this pump drives the liquid through a meter, measurement being performed by the meter in the same manner as in the hydraulic and pneumatic systems. The mechanical simplicity of the hydraulic, pneumatic, and other meter systems are in their favor, as are the steadiness and continuity of flow, and the rapidity with which the liquid may be handled.

It would seem that the size of the meter dials should be considerably enlarged over that which is now commonly found in service, and the fineness of graduation be increased, perhaps to 0.02 gallon. This is necessary in order to make its readings equivalent in nicety to those of other types of commercial liquid-measuring apparatus. In other types of pumps, under proper conditions, the discharge may be determined and repeated within less than 1 cubic inch; this would require the hydraulic-system meter to be readable by estimation to less than 0.005 gallon.

The accuracy in measurement of these metering systems in the forms just illustrated depends upon the precision and reliability of the operation of the meter and the accuracy with which it may be read. A meter for this purpose must be made with extreme care and carefully maintained. The writer's experience shows that in many installations it is found necessary to clean these meters at frequent intervals; this on account of the very small clearances permissible, and the apparent impossibility of clarifying gasoline commercially so perfectly that no solid or sedimentary particles are carried into the discharge stream.

It should be noted here, that in order to obtain the best precision and reproducibility of reading from a water or gasoline meter, a constant rate of flow should be maintained; in some systems this is provided for by arranging for the discharge of liquid

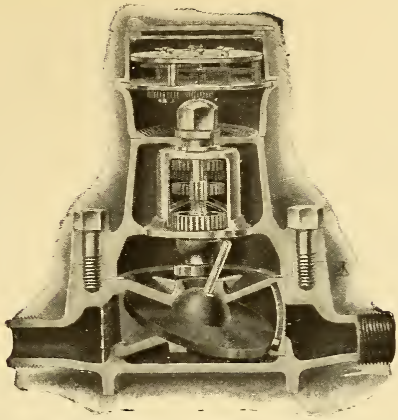

FIG. 9.—*Type of nutating-piston meter, commonly used in connection with the hydraulic and other metering systems*

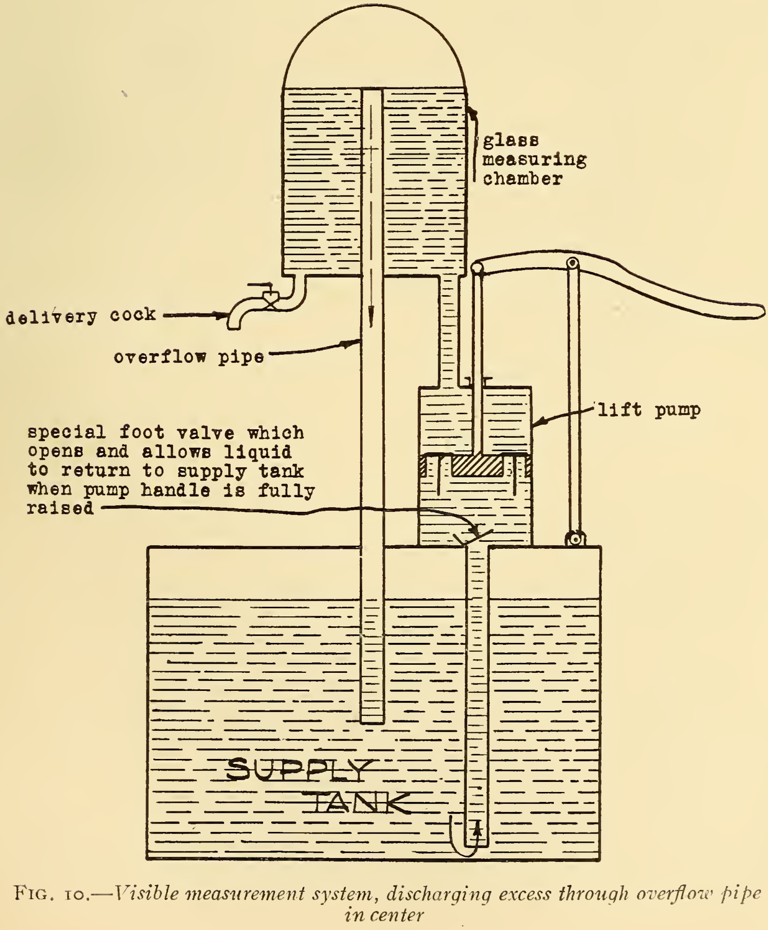

FIG. 10.—*Visible measurement system, discharging excess through overflow pipe in center*

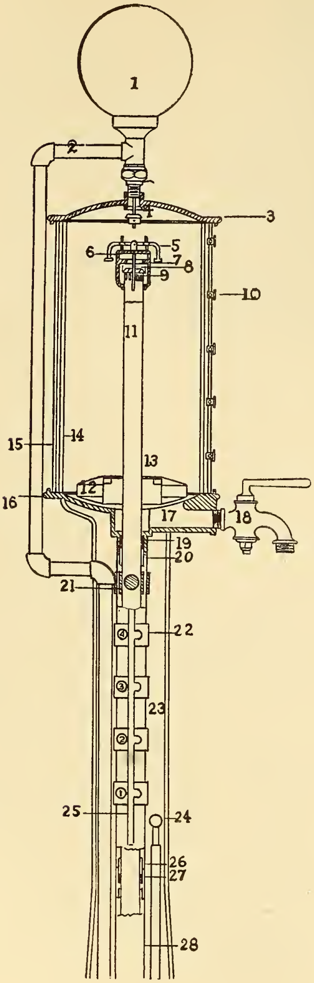

FIG. 11.—*Overflow type, pumping by vacuum. The liquid is forced into the measuring chamber 14 from a convenient supply tank by exhaustion of the air in the chamber. The float 12 rises and shuts off the valve 7. Admission of air through a two-way cock (not shown) allows the liquid in the chamber to drain back to the level of the valve seat. The central tube is adjustable to various heights by engagement with stops, allowing for various units of delivery up to the capacity of the chamber*

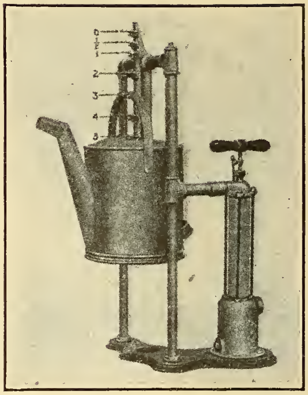

FIG. 12.—*In this type the excess of liquid is abstracted by siphoning back through pump, on opening of the foot valve in the pump base. The different deliveries are obtained by hanging measure on lugs at various heights, indicated by numbers 0, ½, 1, etc.*

under constant head, so maintaining an approximately uniform rate of flow through the meter. For the same reason it is suggested that any valve or cock used in the discharge line for shutting off the stream at the completion of the delivery be of a self-closing type, which can only be maintained at either full or zero opening. This will effectually prevent incorrect registration of the meter due to intentional or inadvertent throttling of the flow.

DEFINITE VOLUME MEASURING-CHAMBER SYSTEMS

A number of measuring-pump systems are founded upon the principle of overfilling a liquid-measuring chamber by adding liquid until an excess is present over the nominal delivery of the apparatus, and then by one of a number of simple expedients, removing the excess, then discharging the adjusted quantity remaining, through a cock or hose in the usual manner. Such pumps are usually made with a glass measuring chamber, in order that the operation of the apparatus and the condition of the liquid may be observed, and that fractional portions may be estimated, or price computation be facilitated.

The initial delivery of the total volume of fluid may be made by any one of a number of means; those commonly employed are the production of a vacuum in the chamber so that the liquid will be forced by atmospheric pressure from the supply tank; forcing of the liquid by application of pressure in excess of atmospheric to the interior of the supply tank; and mechanical pumping. The abstraction of the excess over the nominal delivery can be performed by the same methods.

These details can be better understood by reference to concrete examples shown in the illustrations herewith.

It is suggested that in the types of pumps just described the whole measuring chamber should be clearly visible, so that the presence of sediment or other foreign material, which will act to reduce the initially adjusted volume, can be readily detected and corrected.

GAUGE-GLASS SYSTEMS

Another simple method of liquid measurement is similar to the foregoing, with the exception of the excess abstraction feature just described.

A tall slender tank is provided, either carrying a transparent gauge glass, or itself made of glass. Beside or mounted upon the gauge glass is a graduated scale reading directly in units of volume.

In some cases, instead of a gauge glass a float arrangement is used, the float inside the cylinder being connected by a rod or wire to an indicator outside. This device obviates the danger of breakage which is present when gauge glasses are used, and if properly constructed, will serve the purpose well.

The graduated scale may be securely and permanently affixed, in which case the initial level of the liquid must be adjusted to the zero of the scale, as by discharge at a definite level through an overflow pipe; or it may be slidably mounted, in which case its zero is adjusted into coincidence with the level at which the liquid stands before each delivery is begun. The amount discharged upon the opening of a valve is read by the fall of the liquid column.

It should be noted that in the first case, with the scale permanently fastened, the tank need not be of uniform cross section, since the scale can be calibrated to give correct indications for any given tank, while in the second case, with the slidably mounted scale, the tank must be of uniform cross-sectional area, since the value of a scale interval must be the same for any position of the zero point.

It will be necessary to restrict the permissible diameter of tanks employed in this and similar constructions in order to limit the volume equivalent of a unit length of scale interval. The writer has found a number of such tanks in use in which the diameter was so large that small differences in delivery were quite unreadable. In one installation the tanks were approximately 30 inches in diameter, the graduation corresponding to 1 gallon being but 0.33 inch. Such a high value of volume equivalent per unit of length of graduation interval will be excluded by specification limiting the maximum cross-sectional area of the tank.

WHEELED TANKS

The wheeled tank is coming into wider and wider use, and there are many applications in which it has decided advantages. It is easier and more expeditious to maneuver a portable tank into position for filling a motor car than it is to place an automobile into correct position for filling from a stationary pump. This is especially true of crowded locations, where the maneuvering of automobiles is always accompanied by the danger of striking other cars and stationary objects. There are certain other advantages possessed by the wheeled tank, principal among which is the fact

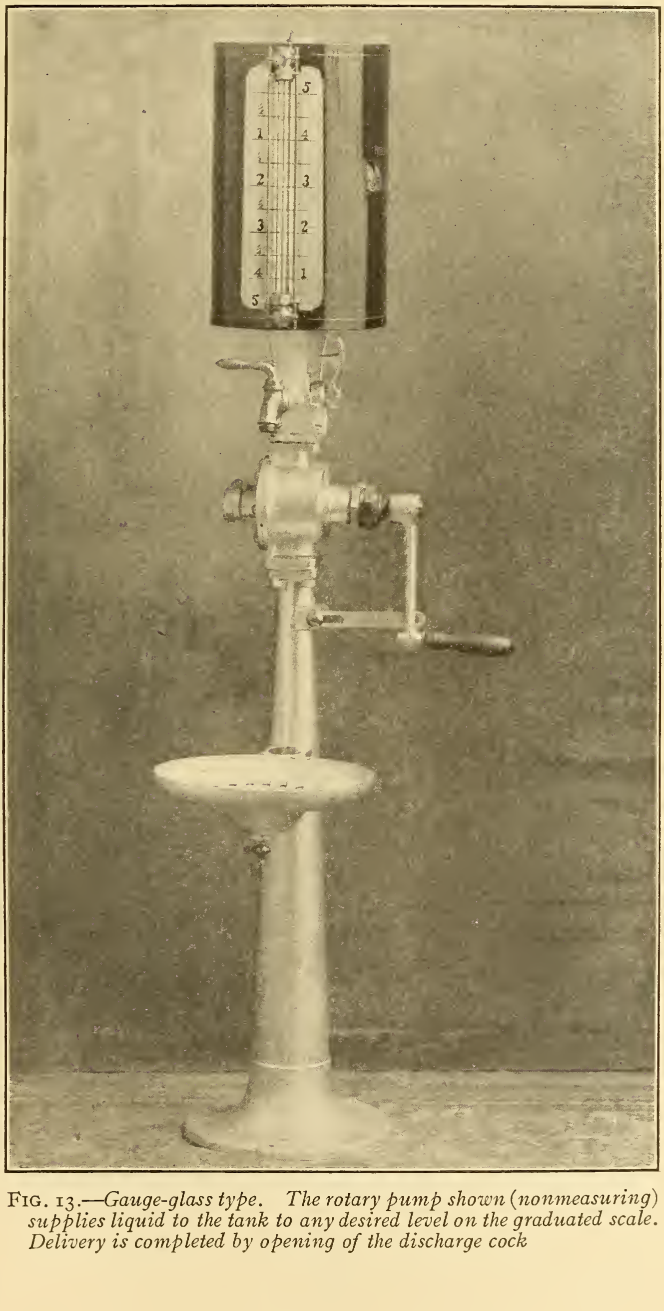

FIG. 13.—*Gauge-glass type. The rotary pump shown (nonmeasuring) supplies liquid to the tank to any desired level on the graduated scale. Delivery is completed by opening of the discharge cock*

that its construction favors accuracy of delivery. In the wheeled tank the pump is carried partly submerged in the liquid, and the tendency toward foaming or vapor formation is very greatly diminished; in addition, the tendency toward leaking back is reduced, and the pump can be expected to deliver its first gallon

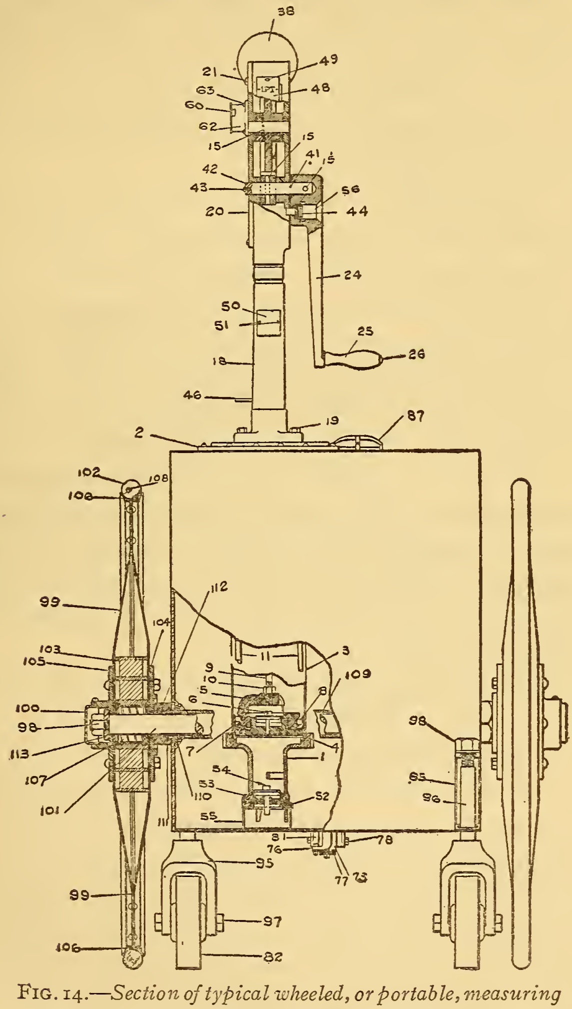

FIG. 14.—*Section of typical wheeled, or portable, measuring pump, showing partial submergence of cylinder parts in the liquid*

after an interval of disuse with much greater accuracy than one connected to a long suction pipe which may require to be partly refilled before discharge at the hose outlet can begin. Wheeled tanks should be provided with splash plates to reduce the liberation of vapor from the contained liquid.

INSPECTION AND TESTING

PIPING AND VALVES

A primary requisite for accurate measurement is freedom from leaks. A piston pump may be readily tested for the presence of leaks in the piston and on the discharge side by tightly closing the outlet valve and performing a number of short strokes until a strong resistance is felt to the motion of the handle. This stored-up pressure the pump should retain for some time, and if appreciable leaks are present in the piston and on the discharge side, they will be noticeable under this test.

However, the presence of leaks in the suction line is still more likely to be fatal to the accuracy of the pump discharge, for several reasons: First, gradual return drainage of liquid stored in the suction line to the tank, on account of leakage of the foot valves or of the suction piping; and, second, the admission of air through leaky suction piping during the continuance of the vacuum which is created on the suction stroke. This admitted air mixes with the liquid, and the pump measurement will comprise a mixture of liquid, air, and vapor. Under such conditions accurate measurement is impossible, and if the pump is adjusted to give an approximate accuracy at a given time with these conditions obtaining, the slightest change in temperature, quality of gasoline, size and number of leaks, speed of operation, and action of operating parts will result in gross inaccuracy of delivery.

Excessive constriction of either the suction or the discharge line may result in faulty measurement. With regard to the suction line, the resulting resistance is a kinetic one operating to increase the virtual suction lift, but in regard to the discharge line it should be noted that partial closing of the discharge valve or the presence of obstructions in the discharge piping may act so as to interpose an abnormal resistance to the liquid stream and on account of the effects of slippage may produce large errors in deficiency. The flow of liquid from the nozzle should be a full, smooth stream. Constricted passages and obstructions near the nozzle are evidenced by a characteristic appearance of eddying and agitation of the discharge stream.

Every effort, then, should be made to install the piping of measuring pump systems with the utmost care, and garage and filling-station owners should be directed to follow with scrupulous exactness the full and explicit directions which most makers furnish as a guide in the installation and operation of their systems.

It would not serve any useful purpose to quote here these instructions, since they can be obtained from measuring pump manufacturers upon request. The inspector of weights and measures can do a real service by giving this advice and supervision in the installation of measuring pump systems, as garage and filling-station owners often disregard the instructions furnished by the makers of the pumps, and so make gross errors in installing their outfits.

HOSE CONNECTIONS

A question which must be carefully considered in the matter of insuring correct delivery from liquid-measuring pumps is the hose which is commonly used in the filling of automobile gasoline tanks. Even the shortest and smallest diameter hose in use hold an appreciable quantity of gasoline; within the writer's knowledge, the smallest diameter of hose in use on gasoline-measuring pumps is about of 0.75 inch internal diameter. A tube 10 feet long of this diameter will contain 53 cubic inches, or nearly 1 quart. There are many gasoline hose in use of 1¼ inches or more internal diameter; such a hose, 1¼ inches in diameter and 10 feet long, will contain 147 cubic inches.

The presence of the hose in the delivery system of the pump introduces an important element of variation in the quantity delivered to the individual purchaser; if the point at which the hose is connected to the pump piping is at a properly chosen height above the highest level at which gasoline will be normally delivered into the gasoline tank of an automobile, the hose will in all parts slope downward, and no liquid will be trapped in it, the whole contents being rapidly drained toward the exit end. If, however, the point of connection of the hose to the pump is low in relation to the point at which the gasoline is discharged to the gasoline tank, a considerable portion of the hose may loop downward below the level of the discharge, and a quantity of gasoline will be retained when the hose is finally hung back into place on the pump, unless the purchaser takes care to lift the low-hanging portions of the hose so as to drain the contents as completely as possible into his tank. It may be said in passing that this expedient is being more and more widely adopted, with the present rise in the price of gasoline. The effect of retrograde sloping portions of the hose in causing short delivery to individual purchasers is one that calls for a remedy, and it is recommended that where hose or flexible tubing is employed in the discharge end of the delivery system, the inner end of the hose be of such height in relation to the length

and stiffness of the hose that all portions of the hose slant downward toward the exit end, in the delivery of gasoline to the highest motor-car fuel tank found in common use.

The writer seriously questions the advisability of the use of a shut-off cock at the end of the delivery hose. The makers and users of pumps frequently maintain that such a cock is necessary to prevent overflowing of the gasoline about the motor car in case more fuel has been asked for than the tank will contain. Observation seems to indicate that the occasions when such overflow would occur are very infrequent and can be entirely eliminated by care and attention on the part of the operator, and that in many cases the presence of a cock at the end of the hose acts so as to facilitate the retention in the hose itself of a portion of the fuel purchased. While this involves no gain to the owner of the pump, it does often involve short measure to the individual purchaser, who often may not obtain the quantity of gasoline in the hose, to which quantity he is fully entitled, unless proper deduction is made from the reading of the pump by measuring it back into a measure. It will surely be admitted that this amount retained will not ordinarily be deducted in reckoning the purchase, and it is therefore urged that this use of a cock at the hose outlet be done away with; it has already been dispensed with by a number of makers. The cock at the pump end of the hose may properly remain to prevent evaporation or accident by loss of liquid from the pump contents.

While measuring pumps will frequently be found in operation under conditions which predicate perfect tightness of valves, it is the opinion of the writer that the valves of a gasoline pump may not usually be relied upon as being sufficiently tight to assure a correct first delivery after the pump has stood unused for a number of hours, as, for example, overnight. Probably when the pumps leave the factory the valves will be tight enough to hold gasoline for long periods. It seems certain, however, when one considers the wear the valves are subjected to in service and the presence of particles of grit and solid matter present in the gasoline, and coming into the gasoline from the interior walls of the piping and the tanks, that perfect or even sensible tightness of check and foot valves is impossible of attainment in practice. This being the case, a proper use of defined-stroke piston type measuring pumps would require that their delivery be not relied upon as accurate after the pump has stood unused for a considerable length of time until at least one correct discharge has been

FIG. 15.—*Excessively long hose due to pump being set back from curb. The practical impossibility of draining such hose into the purchaser's tank is obvious*

FIG. 16.—*Showing hose connection at curb level, making it impossible to secure complete or uniform drainage in service*

FIG. 17.—*Delivery hose outside, pumps inside. Bad practice unless purchaser can clearly observe the operation of the pump from his position outside*

delivered. Another cause of short delivery on the first discharge, which will be taken up in detail under the next heading, is the formation of gasoline vapor under the piston, due to the reduced pressure to which the gasoline is subjected on account of the height of the liquid column above its free surface. The importance of these conditions, and the fact of their existence, may be easily demonstrated by simple tests. It is therefore strongly recommended that users of gasoline pumps—and the same applies to pumps used for heavier hydrocarbons in a lesser degree—be urged to discharge the first cylinderful, after the pump has so stood for a considerable period, into a can or other receptacle, thence to be returned to the storage tank as opportunity may afford.

HEIGHT OF SUCTION LIFT

Attention is here directed to a matter to which neither manufacturers nor users of gasoline pumps appear to have devoted sufficient attention; this is the question of the permissible maximum suction lift. A volatile liquid like gasoline can not be lifted on the suction side of a pump to a height nearly as great as water can be lifted under similar conditions. This is on account of the fact that the vapor tension of the liquid on comparatively small lifts becomes greater than the reduced pressure above the liquid column and boiling-off of a portion of the material as well as liberation of a portion of the dissolved air take place. Gasoline is a mixture of a number of petroleum fractions which have different boiling points and if the boiling point of the lowest boiling of these several fractions is reached by reduction of pressure, that constituent will start to vaporize rapidly with the effect of filling the space under the piston to a greater or less extent with the vapor of that fraction, and the pump, instead of delivering gasoline alone, will deliver a mixture of gasoline, liquid and vapor.

Various manufacturers in their literature advise the limiting of the suction lift to a height of from 10 to 12 feet, but from a few simple experiments performed at the Bureau of Standards this value seems altogether too high, and it appears that a lift greater than 7 feet may be excessive for some of the ordinary commercial grades of gasoline.

For grades of gasoline containing a considerable proportion of light fractions, such as casing-head gasoline, the suction head allowable becomes practically zero. In cases where these very volatile sorts of gasoline are to be lifted with a piston pump, the

usual installation must be modified. Fig. 18 shows a form of installation in which the suction head is reduced nearly to zero, the vertical lift being all obtained on the discharge side. Under such an arrangement the error due to vaporization practically disappears.

Fig. 19 points out the importance of having a continuous slope in one direction from the pump to the supply tank. If there are traps or points of reversing slope in the pipe line, any vapor formed will tend to become lodged at these points and cause irregular and incorrect measurement due to the entrainment of these "vesicles" of vapor.

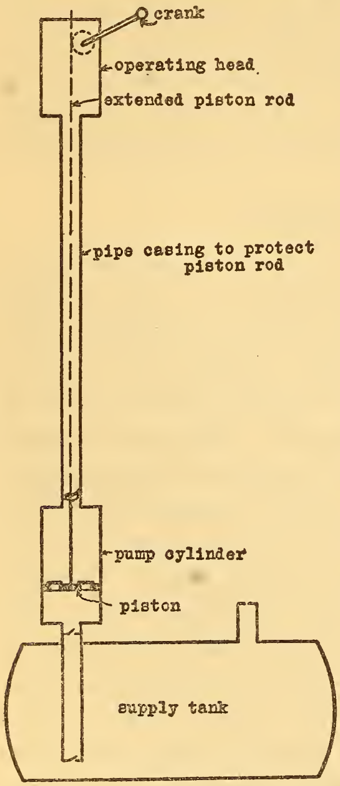

Fig. 18.—*Arrangement of the measuring cylinder at or near the level of the supply tank, employed when the vertical lift is necessarily great, or the liquid to be measured very volatile*

EFFECT OF INERTIA OF THE LIQUID COLUMN

A source of error, the magnitude of which the writer has not yet had opportunity to determine, is the inertia of the moving liquid column. In the usual piston pump, during the delivery stroke, all valves are open in one direction to permit the free passage of the stream. Now, if the stroke be suddenly completed by the contact of the piston rod against a rigid stop, the tendency of the liquid column will be to continue in motion until the energy of its motion is absorbed by the friction of piping, valves, and fittings, and the elevation of the mass against the force of gravity. The energy of this stream is proportional to the product of its mass times the square of its velocity; the inertia error, therefore, can be made a minimum by decreasing the velocity of flow at the expense of the mass of the moving liquid, or practically, by increasing the diameter of the piping.

Pumps having a high rate of delivery may to advantage be equipped with a device which will close a valve in the suction line at the instant the delivery stroke is completed. The only effect of inertia then will be to cause a slight and probably negligible "water hammer."

DEFICIENT DELIVERY DUE TO INCOMPLETE STROKES

Most measuring pumps of the piston type can be made to deliver in deficiency by "short-stroking"—that is, by failing to bring the piston to the limit determined by its stops, at either or both ends of the stroke. This is analogous to incomplete filling or incomplete emptying of a can or measure, and under present conditions must be guarded against by vigilance on the part of the purchaser.

It should be pointed out at this time that it is a matter of no great difficulty to design measuring pumps which can not be fraudulently operated through strokes shorter than the normal. One of the simplest means is the use of the familiar crank and connecting rod mechanism, with the addition of a ratchet to prevent reversal of rotation before the completion of the delivery

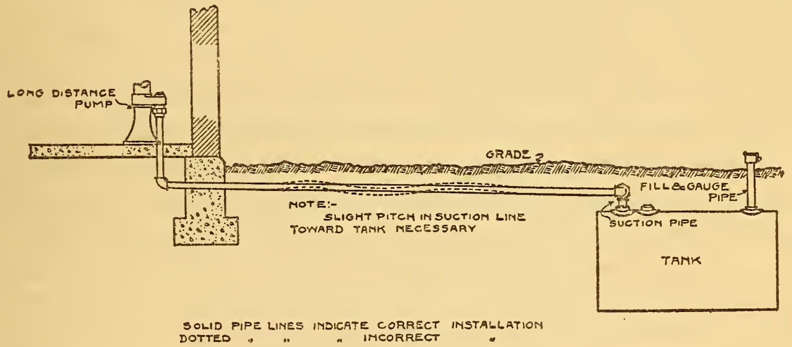

FIG. 19.—*Illustrating correct and incorrect practice in installation of piping. Suction pipe should have a continuous, though not necessarily uniform, pitch from pump back to tank*

and a trigger or snap to hold the crank or handle in place at the initial and final point of the stroke. Such a mechanism will permit adjustment of the discharge to the standard in just as convenient and flexible a manner as those at present employed.

The inspector of weights and measures should exercise a supervision over the ordinary use of piston-type measuring pumps in trade, and satisfy himself that the merchants do not deliver short measure by failure to complete the full stroke. This is a practice which is easy in execution and difficult to establish as a violation of the law, since under some laws intent to defraud is an element of the violation and it is often very difficult to prove that this intent was present. It is the writer's opinion that pumps of the piston type in which incomplete strokes may be performed

should be provided with a placard or sign reading somewhat as follows: THIS PUMP TO DELIVER ____ GALLONS ON EACH FULL STROKE.

A means to fraud which should be guarded against is the by-passing of a portion of the discharge stream back into the supply tank. Any piping connecting the discharge side of the pump to a tank or basin may be looked upon with suspicion. A number of types of measuring-chamber pumps may be so operated as to allow the return of liquid to the supply tank at the same time that the discharge to the customer is taking place. These pumps should be so modified that the operation of returning to the supply tank the liquid stored in the measuring chamber can not be performed except by a mechanical device, the purpose and action of which are clearly perceptible to the purchaser, or, better still, which can not be operated while the regular outlet is open.

A number of instances have come to the writer's attention in which garages have in service a measuring pump which is used merely for filling wheeled tanks or cans and not as a measuring device, unless perhaps as a check on the distribution of gasoline at various selling pumps. In cases of this kind in which the inspector is assured by the owner that the pump will not be used directly in the sale of gasoline to consumers, the pump need not be tested and sealed, provided that steps are taken to insure against its being used as a measuring instrument. This can be simply done by placarding such pumps with a sign reading somewhat as follows: THIS PUMP IS NOT TO BE USED FOR MEASURING PURPOSES.

In no case should the inspector permit a pump to be left uninspected and unsealed, unless some precaution of this kind is taken to prevent its use for measuring purposes.

ROUTINE OF TEST

In testing a measuring pump the hose may often be removed and the test deliveries taken directly from the pipe outlet. In other installations a can-filling outlet is provided; in such cases the valve at the inner end of the hose should be tightly closed, and the test deliveries taken from the can-filling outlet.

Determine first the accuracy of the initial delivery of the pump as found, beginning with the handle in the correct starting position. The error will be determined in this manner: Have ready a standard measure of capacity equal to the nominal discharge of the pump for each full stroke, if this size measure is available, and

start pumping into the measure at about the normal speed of operation of the pump, intercepting, however, during the process, a portion of the discharge into a straight cylindrical graduate of about 35 cubic inches capacity. When the discharge of the pump is completed, and the operating handle returned to its starting position, see that the standard measure is accurately level, and pour from the graduate into the measure until the latter is exactly full, or until no more liquid remains in the graduate. If the pump is delivering in excess a portion of its discharge will remain in the graduate after the standard measure is exactly filled, and this quantity may be read off as the error of the pump in excess.

If the pump is delivering in deficiency, the amount in the graduate will be insufficient to fill the standard measure, and a suitable amount of liquid in addition may be poured into the graduate from any convenient supply, the reading of the graduate being noted. Then pour from the graduate into the standard measure until the latter is exactly filled, and again read the quantity of liquid in the graduate. This value subtracted from the reading of the graduate just taken will be the error of the pump in deficiency.

The set of readings taken as above will determine the error of the pump as found. Now, readings may be taken to determine the action of the pump when operating under the conditions of service. Proceed in the manner above described, operating the pump at a slow speed for one determination, and at high speed for the next determination, noting the error in each case. If either of the determinations just described is in error in excess of the tolerance allowable, the pump should be recommended for repair or adjustment. The two speeds used for the tests just outlined should be considerably different, one faster than normal operation and one slower than normal operation. Neither speed, however, should be greatly outside the range which may be expected to occur in actual use of the pump.

Slicker plates may or may not be used in the work with the test measure, according to the precision desired. The use of slicker plates will undoubtedly give better results, and will serve to impress observers with the need for care and accuracy in this work.

A simple and useful form of testing standard, which can be constructed in the 1 and 5 gallon sizes, will serve all the ordinary purposes of field testing of measuring pumps. This graduate is

shown in Fig. 22. By using this measure, the design of which is due to Theo. Seraphin, of the office of the county commissioners, Philadelphia, the determination of the error of delivery for all ordinary ranges of error becomes merely a matter of reading off the height of the liquid surface on the graduated scale of cubic inches shown. This measure can be readily hung upon the delivery tap of the pump, or it can be set upon the floor under the pump, as circumstances may dictate. While this measure is not at present on the market, it can doubtless be constructed to order

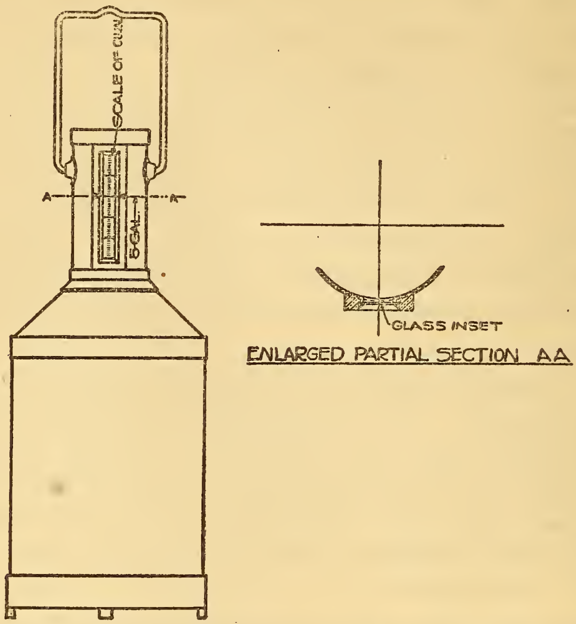

FIG. 22.—*Seraphin type of testing measure for field use, graduated for direct determination of excess or deficiency within the ordinary range encountered*

at a moderate price by any one of a number of firms making similar apparatus.

If a measuring pump is in good mechanical condition, and its design and installation are not grossly incorrect, the amount of liquid delivered should be nearly, if not quite, independent of the speed at which it is operated, at least over all ranges of speed which are practicable for manual operation. Exception should be noted, however, to this statement, in those cases in which the storage tank is so far below the cylinder of the pump that excessive reduction of pressure accompanied by volatilization occurs in the liquid column when the piston is rapidly operated. This

FIG. 20.—*Testing with a 5-gallon standard, slicker plate, and graduated cylinder. A conical 1-gallon measure is seen at the left*

FIG. 21.—*In testing outfits which have a low hose connection, care must be taken to insure drainage to a constant level if complete drainage of the hose is not feasible. In this illustration the inspector is supporting the discharge cock at the level of the top of his standard measure. A stand or support might well be supplied for use in such cases. Note that the pump in the background must force the measured liquid through a long pipe line under the sidewalk*

effect is heightened by the presence of excessive resistance in the suction line, such as will be consequent upon the presence of numerous elbows and valves, excessive length of suction piping, or constrictions in the pipe.

The inspector should assure himself by trial that the counter or tallying device, whatever its type, gives correct indications. He should see that it does not skip any numbers as the pump is operated and that it does not fail to advance one number for each complete cycle of operation. If the counter is found to be unreliable, it should be removed, or else deranged in such a manner that it does not indicate at all, pending the performance of proper repairs.

The inspector may require that the counter be clearly visible to both the customer and the operator, and that its indications be legible and not obliterated by dirt or wear. There is an increasing and commendable tendency for manufacturers to increase the size and legibility of the counters, and to place them in positions where their indications can be more easily observed.

The integrating counters with which many pumps are fitted are not of paramount interest or importance to the inspector of weights and measures, since their indications figure principally in the dealer's computation of his profits, losses, and sales, and do not directly affect the purchases of the liquid commodity. However, such counters sometimes go amiss, and lead to false conclusions on the part of the dealer. Where such counters are shown on actual trial by counting of strokes to be reading incorrectly, they should be sent to the makers of the pump or their agents for repair.

A number of cases have been noted in which there was an actual siphoning of gasoline from the tank or from the filter chamber. Such siphoning is particularly likely to occur in the case of the wheeled tank, due to the fact that the end of the hose can be brought to a point below the level of the liquid in the tank; the difference in head resulting is sometimes sufficient to raise the lift valves in the system and discharge a continuous stream without operation of the pump. In the case of stationary pumps with tanks below grade, a similar action can occur by infiltration of air through a point of leak at any place above the height of outlet. Some makers have eliminated the siphoning by introducing into the discharge piping a spring check valve, which will not open except under the relatively high pressure occurring during the actual operation of the piston. Such a valve is desirable from

the point of view of safety as well as from its effect in reducing the likelihood of excess delivery from the causes just outlined.

This siphoning action should not be confused with the gradual spillage which is often noted as a result of the expansion of the liquid in the pump chambers, due to an increase in temperature by conduction through the cylinder walls, this action sometimes occurring when gasoline is brought from a tank in which it is kept relatively cool to a warmer region outside.

In connection with this topic of thermal expansion it is to be noted that cases of short delivery are sometimes explicable on the basis of contraction of volume of the liquid contained in the pump due to a fall in temperature, as from evening to the next morning. This contraction in volume will amount to about 0.1 per cent for 1° C. It is unavoidable in the nature of things and suggests again the need of pumping through a quantity of gasoline before the pump is used for measurement after a period of disuse.

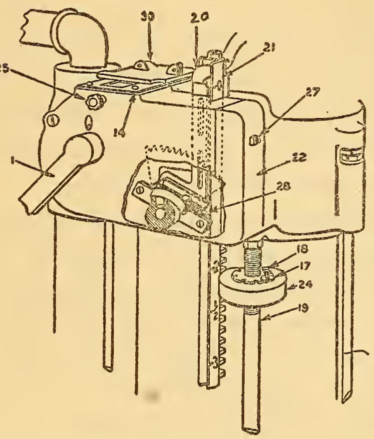

Fig. 26.—*The stop on this pump is sealed by inserting a lead seal into a hole in the upper end of the pin passing through washer No. 17*

SEALING

After the pump has been tested and found correct, or has been adjusted by the inspector so as to deliver correctly the indicated amount of liquid on repeated trials, it should be sealed. On account of the great diversity in the types and details of construction of the many pumps on the market, it will be impossible in the space available fully to cover the methods of sealing each of the forms of measuring pumps; we must be content to lay down a general principle and illustrate it by a few examples.

Obviously, a seal should be applied to every accessible part of the pump upon which an adjustment can be made which would directly affect the amount of liquid delivered. In the piston type of pump this will always require the individual sealing of the several piston limit stops; if the stop bar is threaded to permit the rotation of the stops for the purpose of primary adjustment, the alteration of the setting of the stops can be prevented by sealing in place the rod which limits the rotation of the stops upon the threaded bar. This rod can be clearly seen in Fig. 25.

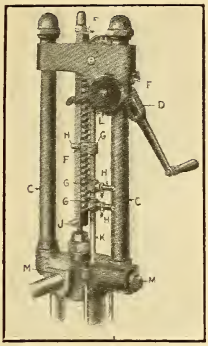

FIG. 23.—*For sealing stops like those shown above, seals must be passed through holes in the screws marked* H *so as to engage with the slots or kerfs cut into the cast lugs in which these screws are supported*

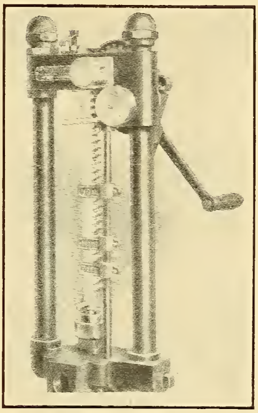

FIG. 24.—*In this type the piston stops are split vertically and may be made secure against alteration by passing a seal through one end of the screws which hold together the two halves of the stop*

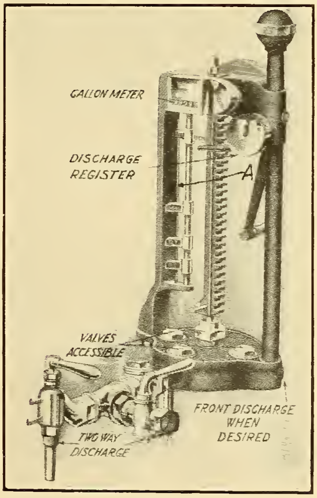

FIG. 25.—*In this type the alteration of the stops is prevented by a vertical rod* A *which prevents the stops from being moved up or down along the screw. To secure them against alteration it is only necessary to seal in place the vertical rod* A; *provision for such sealing being usually made at its lower end*

In one make of pump the limit stops, instead of coacting with the piston rod itself, are carried upon a gear wheel meshing with a rack which forms an extension of the piston rod, as shown in Fig. 27. These stops are usually set screws threaded through cast lugs projecting from the face of the gear wheel. In order to seal stops of this type it will be necessary either to drill straight through the lugs and their contained screws, and pass the wire seal through this hole, or to seal in place the cover of the case in which the gear is contained, in such manner as to prevent effectually all access to the adjustable parts.

The type of piston stop in which the security and permanence of the fastening depends upon the friction of a set screw upon a smooth rod can not be considered satisfactory. Sealing of this type of stop by a metal cap designed to make the head of the set screw inaccessible does not provide sufficient security, and the only safe recourse is to drill completely through the lug and stop bar, driving in a tightly fitting headed pin, passing the usual wire seal through a hole in the unheaded end of the pin.

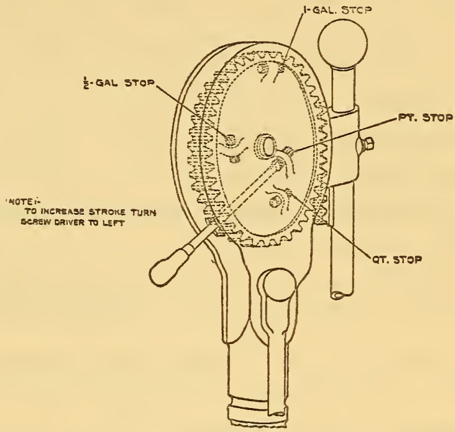

FIG. 27.—*The adjustments of this type are usually secured by sealing shut the case inclosing the gear. If this can not be done, or if there are slots in the gear case through which the screws may be reached from the outside, holes should be drilled through the set screws in the interior of the case and the usual seal wires passed through these holes to prevent the screws from being moved*

Care should be taken in all cases to attach seals in such a manner that they can not interfere with the proper operation of the pump. The wires should be drawn up short so that the lead seal lies snugly against the part secured.

The seals used for measuring pumps should be of a strong, heavy type; exposure of the pump to out-of-doors conditions and to hard use and abuse requires the use of seals having heavy tinned braided wires and a lead disk large enough to afford secure clamping of the ends of the wire.

RECORDS

While the writer realizes the difficulties which frequently confront the weights and measures inspector in testing and supervising a large amount of apparatus with a limited force, it is his opinion that the best results are to be obtained only by keeping rather full and detailed records of inspections. By so doing the inspector will develop a quicker and keener faculty of observation and will grow to be more thorough in the work. Moreover, the offering of such complete and explicit data in hearings and in court will not fail to be impressive and convincing, and will enable the administrative officer to deal more surely and expeditiously with violations which may occur. The following form is suggested as one which has been used in extensive field work; it will be found to comprise most of the information which will be required in the routine inspection and testing of measuring pumps. It is of course subject to such modification as may be needed to bring it into conformity with particular needs.

Test of Liquid-Measuring Pump Test No. ——

City..............................

Date..........................

Owner...Address..

Maker of apparatus..Inspector.....................................

Type of apparatus...Maker's No. ....

Nominal delivery per stroke..............gal.

Graduation of meter, measuring cylinder, gauge glass or counter............gal. x ....gal.

Selling price of commodity on date: ....c. a gal.

Hose length............feet. Hose diameter, internal, ...inches.

Number of observation	Speed [a]	Nominal discharge	Error (+ or −)	Within tolerance	Without tolerance	Remarks
1	....	....	....	....	....	....
2	....	....	....	....	....	....
3	....	....	....	....	....	....
4	....	....	....	....	....	....
5	....	....	....	....	....	....
6	....	....	....	....	....	....
7	....	....	....	....	....	....
8	....	....	....	....	....	....
9	....	....	....	....	....	....
10	....	....	....	....	....	....

Is hose high enough to insure satisfactory drainage? ....

Does counter operate correctly? ....

Other notes..

....

....

Test full stroke as found and after use.

Test or remove fractional stops.

[a] Slow, normal, or fast; or give, in seconds, time required for stroke.

CONDITION OF PUMPS IN SERVICE

Of 79 measuring systems of various types chosen at random and tested by the writer in a number of different cities, 55, or 70 per cent, had errors in excess of the tolerance allowable, and 24, or 30 per cent, had errors within the tolerances. In addition, there were eight outfits so constructed as to be absolutely unsuited for retail liquid dispensing. Of the 55 out of tolerance 80 per cent gave deliveries in deficiency and 20 per cent in excess. This tendency toward deficient measurement is worthy of careful consideration, and it is only proper to call attention to the fact that most of the causes of error in measuring-pump operation tend toward the side of deficient delivery.[1] Among these may be mentioned leaks, retention of liquid by the hose, excessive virtual suction head, resulting in vaporization and other losses, failure to complete the full stroke, and slippage.

CONCLUSION

The results of this investigation will be placed at the disposal of the tolerance committee of the conference and will form the basis for such specifications as may be required in the normal progress in this field. Suitable specifications suggested by the results of this work will probably be presented at the next annual conference, and in the interim the Bureau will treat particular inquiries from weights and measures officials and manufacturers in the light of the best information now in hand.

The Bureau will endeavor to maintain a full and up-to-date mailing list of the makers of measuring pumps, and will strive to keep in touch with current progress in the design of this apparatus.

Thanks are due a number of city weights and measures officials who gave valuable aid in the work of this investigation, and to manufacturers of measuring pumps generally, who in a gratifying manner furnished drawings and other data and afforded the writer an opportunity to visit their factories and study the methods of manufacture.

WASHINGTON, June 30, 1916.

[1] Since the above was written, a great amount of additional field work has been done and the results show conditions generally to be in serious need of correction by thorough and regular supervision. The results of these later investigations are available in the form of a mimeographed circular, which will be sent to those who request it.